Technology Strategy Board
Driving Innovation

Retrofit Revealed

The Retrofit for the Future projects – data analysis report

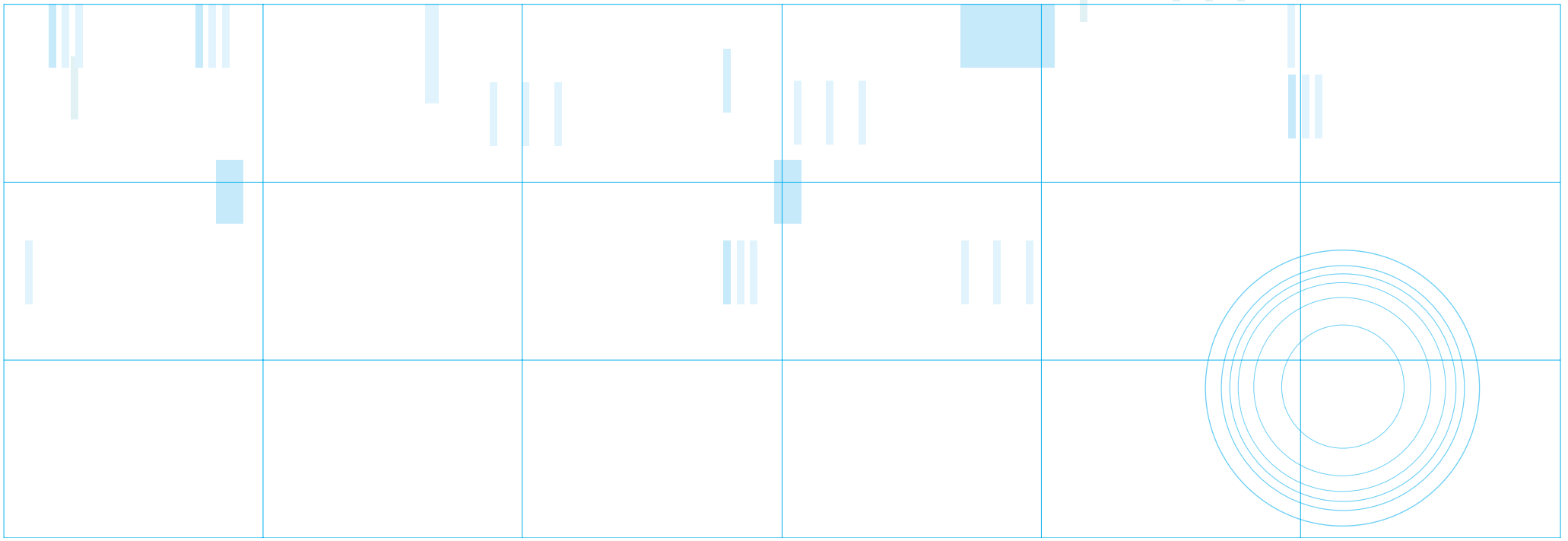
About the Technology Strategy Board

The Technology Strategy Board is all about driving innovation.

We are the UK's innovation agency. We accelerate UK economic growth by stimulating and supporting business-led innovation.

We are a public body operating at arm's length from Government and sponsored by the Department for Business, Innovation and Skills.

Our vision is for the UK to be a global leader in innovation and a magnet for innovative businesses, who can apply technology rapidly, effectively and sustainably to create wealth and enhance quality of life.



Contents

Summary

This report presents the first analysis of data collated from the Technology Strategy Board's Retrofit for the Future programme, and a review of the final reports submitted by the Retrofit for the Future project teams.

Retrofit for the Future acted as a catalyst for the retrofit of over 100 homes across the UK, with an ambition of achieving an 80% reduction in the in-use CO_2 emissions of each property. The properties were mainly two-storey dwellings, with a couple of bungalows included too. All homes had two or more bedrooms.

We have analysed the monitoring data provided by the Retrofit for the Future project teams, to:

- identify the energy and carbon performance achieved by Retrofit for the Future projects
- explore whether this performance is being achieved at the expense of other factors, such as occupant comfort or satisfaction
- identify common success factors, lessons and challenges from the delivery of Retrofit for the Future projects, to provide insights to the industry.

Key findings

Of 37 properties included in this analysis, three achieved a reduction in CO_2 emissions equivalent to over 80% compared with 1990 average levels. A further 23 achieved a reduction in CO_2 emissions equivalent to between 50% and 80%.

The analysis shows a strong correlation between good air-tightness and lower CO_2 emissions. The data also suggests that air-tightness and emissions reductions are usually being achieved without compromising the comfort of residents. Almost all of the properties in this analysis stayed within comfortable boundaries for temperature and relative humidity.

This analysis also considers energy costs. Our analysis includes data for all gas and electricity consumed for heating, hot water, lighting, white goods, plug loads, etc. We have excluded from our analysis those properties known to contain a biomass boiler. The lowest property has estimated gas and electricity costs of £374 per year. Three more are below £500 per year, and three more are between £500 and £600 per year.

Of 37 properties included in this analysis, three achieved a reduction in CO_2 emissions equivalent to over 80% compared with 1990 average levels. A further 23 achieved a reduction in CO_2 emissions equivalent to between 50% and 80%.

What makes a successful retrofit project?

Our analysis of the final reports submitted by project teams has enabled us to summarise many of the challenges faced, and the steps taken or ideas generated by the industry to overcome these challenges. It has also given us a snapshot of some of the success factors which seem to drive effective retrofit projects. These are summarised in the table below.

Project planning

Time spent in detailed pre-design

Researching the market for products and suppliers early on

Detailed and realistic project planning, including extensive contingency planning and risk management

Careful sequencing of works, enabled by well co-ordinated procurement

Site management

Dedicated co-ordination of the retrofit project

Engaging and motivating the project team early on

Open and frequent communication between project team members

Understanding among site staff of the importance of achieving good air-tightness

Understanding the supply chain

Building relationships with manufacturers

Anticipating the availability, price and lead times of innovative products

Working with the suppliers of control systems to ensure that those installed are fit-for-purpose and simple to understand

Working closely with residents

Engaging residents early and frequently in the process

Decanting residents

Helping residents to understand how to manage their homes at different times of the year by explaining system controls

Training support staff (call centre, maintenance) to provide informed, ongoing help to residents

The future for retrofit

Our analysis suggests that there are considerable challenges ahead for the retrofit market. Equally, we have identified some concrete examples of innovation, and further opportunities for product and service development, which we are hopeful that industry will grasp.

To support the development of a thriving retrofit market in the UK, the Technology Strategy Board has made the full data set from Retrofit for the Future available through a database called ‘embed’. This database provides a valuable resource for anyone considering a retrofit project. It can be accessed via **www.retrofitanalysis.org**

We have also launched a follow-on competition: Scaling-Up Retrofit of the Nation’s Homes (https://connect.innovateuk.org/web/retrofit). The competition opened on 4 March 2013. To enter, you must register by noon on 10 April 2013 and submit an Expression of Interest by 17 April 2013.

Introduction

The Retrofit for the Future competition was designed to address the challenge laid down by the UK Government's target to reduce greenhouse gas emissions by 80% by 2050. The competition was co-ordinated by the Technology Strategy Board with the endorsement of the Department for Communities and Local Government and the Homes and Communities Agency.

Retrofit for the Future acted as the catalyst for the retrofit of over 100 homes across the UK, with an ambition of achieving an 80% reduction in the in-use CO_2 emissions of each property. We have analysed the monitoring data provided for these homes and considered the final reports provided by the project teams involved. Our aims were to understand what was achieved and to draw out lessons to inform successful low-carbon retrofit in the future.

The analysis presented in this report sought to:

- identify the energy and carbon performance achieved by Retrofit for the Future projects
- explore whether this performance is being achieved at the expense of other factors, such as occupant comfort or satisfaction
- identify common success factors, lessons and challenges from the delivery of Retrofit for the Future projects, to provide insights to the industry.

This report is designed to help anyone with an interest in low-carbon retrofit. We hope that it will help practitioners and professionals to understand the extent to which CO_2 reduction targets can be achieved right now, using existing technologies and practices. We would like academics and students to consider our findings and ask their own research questions of the underlying data set which is available online. And we expect that policy-makers and specifiers of low-carbon retrofit projects, such as housing associations and local authorities, will see these findings as a useful guide when developing new mechanisms for accelerating the implementation of retrofit in the coming years.

You can find out more about the Retrofit for the Future programme at **www.retrofitanalysis.org**

Retrofit for the Future

Retrofit for the Future aimed to inspire and act as a catalyst for the retrofit market by showcasing innovative approaches to low-carbon retrofit. 194 projects were funded with up to £20,000, to develop strategies to achieve an 80% reduction in CO_2 emissions in an existing property. 86 projects were then awarded additional funding of up to £150,000 to enact those strategies and demonstrate just what could be achieved. Some of the projects even tackled more than one home, resulting in over 100 homes being retrofitted.

Retrofit for the Future was run as a competition, with project teams encouraged to innovate and to demonstrate creativity and flexibility in the approaches they took. We wanted to explore the realm of the possible – just how low could we drive CO_2 emissions in today's housing stock using today's technologies and practices?

86 projects were awarded funding of up to £150,000 to demonstrate just what could be achieved.

The competition process brought significant surprises and advantages. Targeting social housing led to the active involvement and leadership of housing associations, who identified suitable properties and amenable residents, supported the works as they progressed, and showed a willingness to take risks. Social housing homes were selected for this programme for practical reasons, but most of the lessons learnt will apply across all tenures.

The competition process also demanded that different disciplines across the industry worked in close partnership to deliver integrated solutions. It recognised and rewarded innovation whilst allowing project teams to take risks. It placed as much emphasis on understanding what went wrong as on celebrating the things that worked well.

In developing this report, we faced some challenges related to the competition process. We had 86 live experiments under way, using various technologies and approaches to monitoring performance. We have applied a standard set of tests and reviews across the projects, comprising before-and-after air permeability tests, thermography studies, post-construction reviews and occupancy surveys. A standard specification for long-term energy and environmental monitoring was provided to all projects, although this allowed for flexibility in the selection of equipment. The following section explores the strengths and weaknesses of the resulting data set in more detail.

The data set continues to grow as more projects report their findings. The data is being gathered in a database called embed, developed in collaboration with the Energy Saving Trust and AMEE. This database is open to anyone with an interest in low-carbon retrofit – whether they are academics, policymakers, practitioners, commissioners, specifiers or students. We encourage further analysis of the data so that we can continue to learn about the effective delivery of low-carbon retrofit in the UK's housing stock.

With the Retrofit for the Future programme, we were not conducting a field trial of one single approach or technology, but rather overseeing a living laboratory running over 100 different experiments. Whilst a specification for measurement and monitoring was given, it was up to each individual project team to select their own approach.

To measure the energy performance of individual properties after retrofit, we needed a number of pieces of data:

- at least one year of electricity data
- at least one year of gas data, if the property uses gas
- gross internal floor area (this enabled us to normalise the post retrofit CO_2 emissions to a common metric of $kgCO_2$ / m^2 / year).

A living laboratory running over 100 different experiments

For the analysis in this report, we identified 37 properties with this data available. They are a mix of detached, semi-detached and terraced properties. They are mainly two-storey dwellings, with a couple of bungalows included too. All have two or more bedrooms.

The CO_2 emissions of each property were subsequently calculated using carbon dioxide emission factors for each fuel type.

We have also analysed monitored data and feedback from residents on comfort levels (eg internal temperatures and humidity levels) to explore the impact on comfort when improving the energy performance of a property.

A detailed explanation of our methodology can be found at **www.retrofitanalysis.org**. On the same website, you can view additional information and graphs generated by our analysis, such as energy use per occupant and the use of particular technologies in different properties. More data will appear in the database in the months to come.

The second half of this report focuses on the final reports submitted by 54 of the Retrofit for the Future project teams. We reviewed these reports to identify three things:

- aspects of project delivery which were seen as successful
- lessons learned during delivery of the projects
- challenges that individual teams were unable to address during the delivery of their projects.

Calculating an 80% reduction in CO_2 emissions

Comprehensive data on the energy usage of each property prior to retrofit was not required as part of the competition; instead the Energy Saving Trust calculated a proxy target for the achievement of an 80% reduction in CO_2 emissions. The 1990 national average performance for a three-bedroom semi-detached property was normalised by the average gross internal floor area for the same property type. An 80% reduction from these figures led to a primary energy target of 115kWh / m^2 / year and an emissions target of 17 kg CO_2 / m^2 / year.

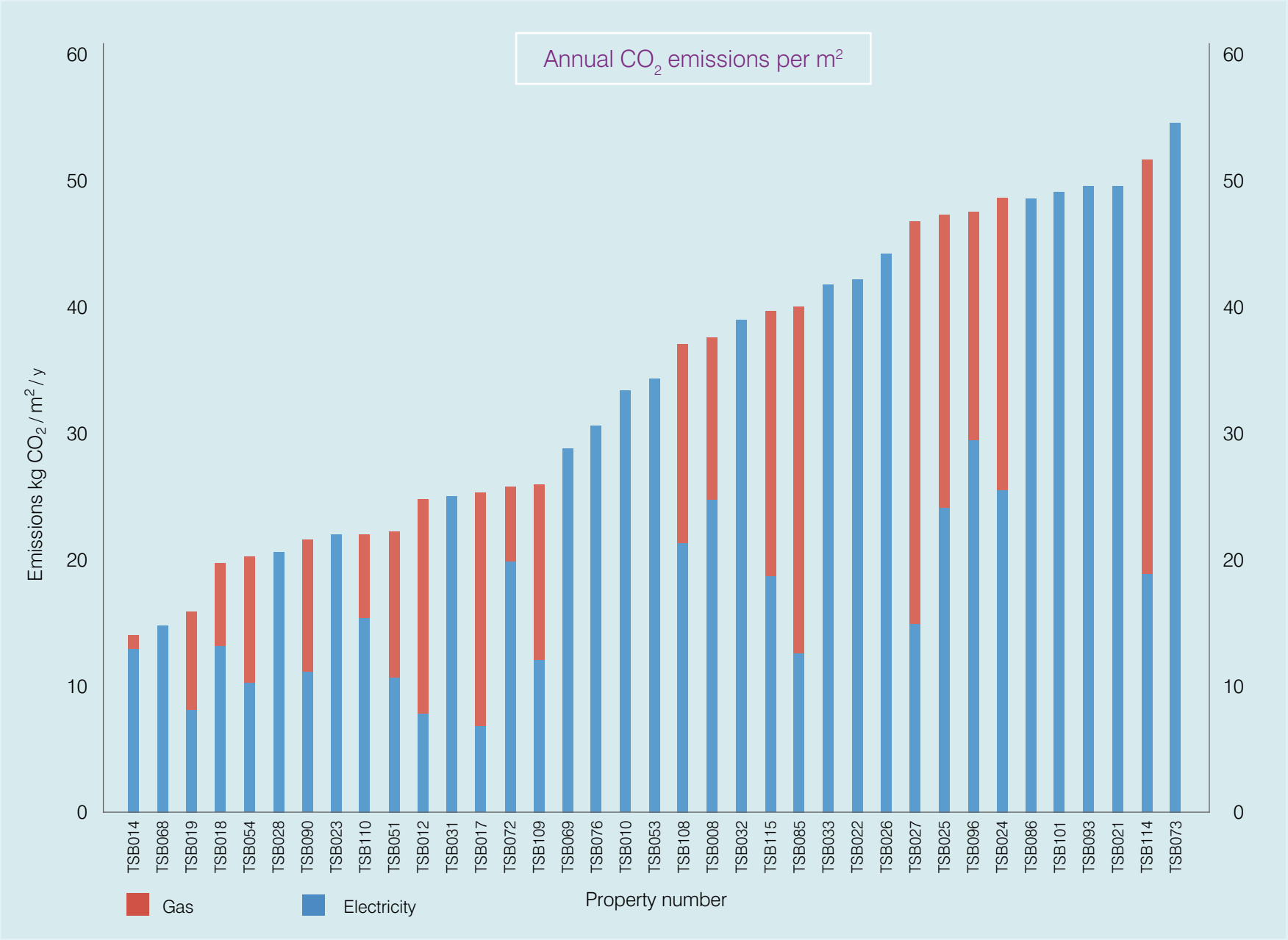
What CO_2 emissions reductions did Retrofit for the Future projects achieve?

The following chart shows emissions in kg CO_2 / m^2 / year for each of the properties we have analysed.

Three of the properties achieved reductions beyond the 80% target of 17 kg CO_2 / m^2 / year. The same three properties also had primary energy consumption of less than 115kWh / m^2 / year. A further ten properties achieved CO_2 reductions equivalent to 70% – 80%. A further thirteen achieved CO_2 reductions equivalent to 50% – 70%.

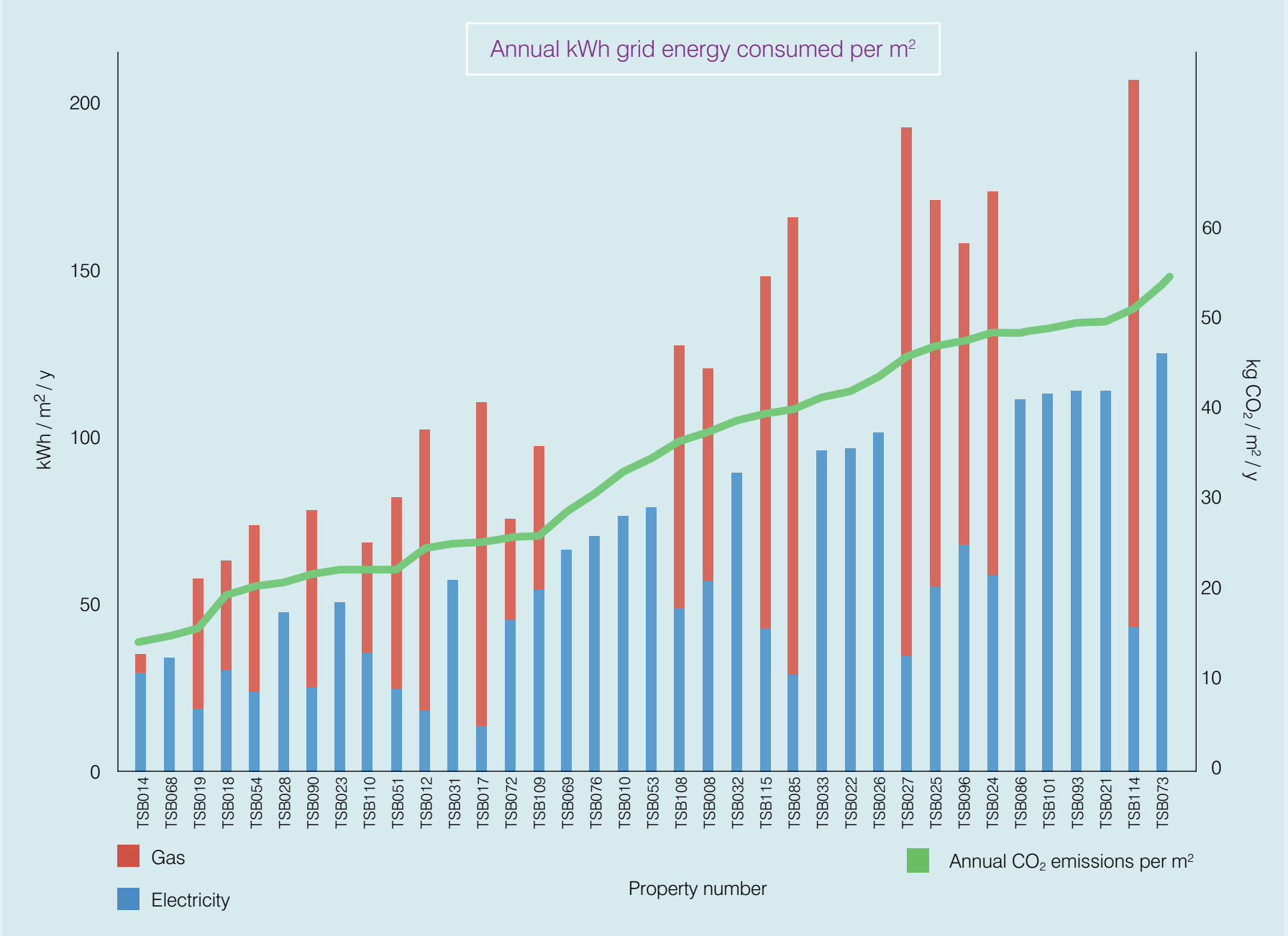
This inspires confidence that CO_2 emissions reductions in excess of 50% and as high as 70% or more can currently be achieved by a range of organisations and delivery teams in the UK low-carbon retrofit market.

You can find out more about the work undertaken on each of the Retrofit for the Future properties at **www.retrofitanalysis.org**


Annual CO_2 emissions per m^2
Emissions kg CO_2 / m^2 / y
0
10
20
30
40
50
60
TSB014
TSB068
TSB019
TSB018
TSB054
TSB028
TSB090
TSB023
TSB110
TSB051
TSB012
TSB031
TSB017
TSB072
TSB109
TSB069
TSB076
TSB010
TSB053
TSB108
TSB008
TSB032
TSB115
TSB085
TSB033
TSB022
TSB026
TSB027
TSB025
TSB096
TSB024
TSB086
TSB101
TSB093
TSB021
TSB114
TSB073
Property number
Gas
Electricity

What do we know about the energy consumed in Retrofit for the Future properties?

The following chart shows the split of metered energy between gas and electricity usage in the properties analysed, normalised by their gross internal floor area (ie. kWh / m^2 / year). The properties are sequenced in the same order as in the previous CO_2 emissions chart. The data is from the incoming gas and electricity meters; therefore the chart implicitly takes account of any electricity used to power on-site energy technologies, such as solar thermal circulation pumps. The chart does not, however, identify any heat or electricity that is generated on-site, such as from a biomass boiler or solar PV.


Annual kWh grid energy consumed per m²
kWh / m² / y
kg CO₂ / m² / y
0
50
100
150
200
0
10
20
30
40
50
60
TSB014
TSB068
TSB019
TSB018
TSB054
TSB028
TSB090
TSB023
TSB110
TSB051
TSB012
TSB031
TSB017
TSB072
TSB109
TSB069
TSB076
TSB010
TSB053
TSB108
TSB008
TSB032
TSB115
TSB085
TSB033
TSB022
TSB026
TSB027
TSB025
TSB096
TSB024
TSB086
TSB101
TSB093
TSB021
TSB114
TSB073
Gas
Electricity
Annual CO₂ emissions per m²
Property number

What do we know about air-tightness in Retrofit for the Future properties?

The air-tightness of properties was tested both before and after the retrofit works. We have comparable results for 87 properties.

The pre-retrofit results were surprising, as most properties were below 10 m^3 / m^2 / hr@50Pa. This meant the scope for improvement for many project teams was in fact less than originally assumed. At the same time, thirteen of the 87 pre-retrofit results were greater than 15 m^3 / m^2 / hr@50Pa, and these properties offered scope for considerable improvement.

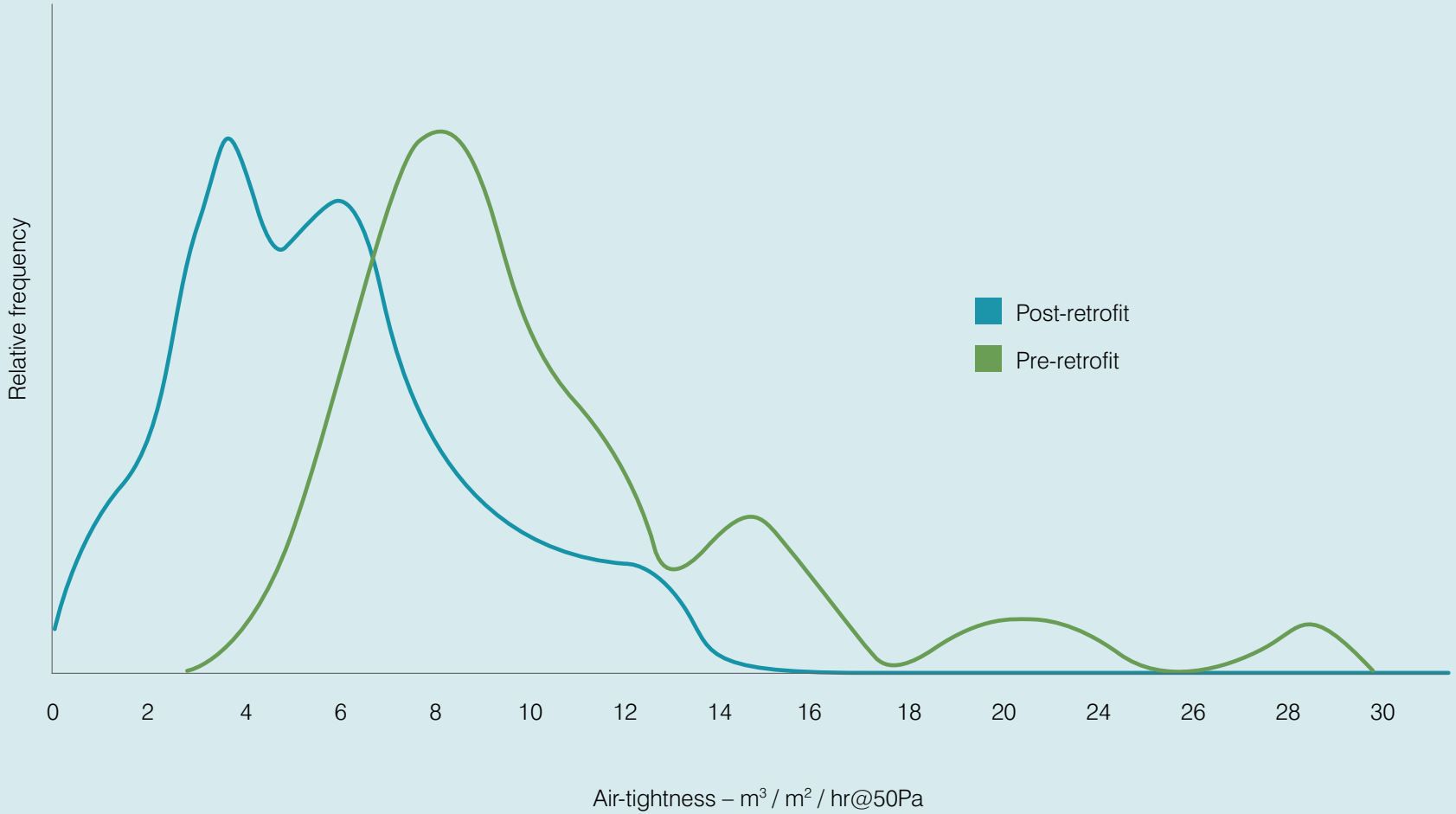
The following chart illustrates the degree of improvements made, by plotting the relative frequency of the air-tightness result on two lines. One line shows the results pre-retrofit and the other line shows the results post-retrofit. The most frequent air-tightness result was improved from a pre-retrofit value of ~8 m^3/ m^2 / hr@50Pa to a post-retrofit value of ~4 m^3 / m^2 / hr@50Pa.

Before retrofit, only two properties had air-tightness less than 5 m^3/ m^2 / hr@50Pa. Post-retrofit, there were 39 properties less than 5 m^3/ m^2 /hr@50Pa, and five of these were less than 1 m^3 / m^2 / hr@50Pa

Five properties

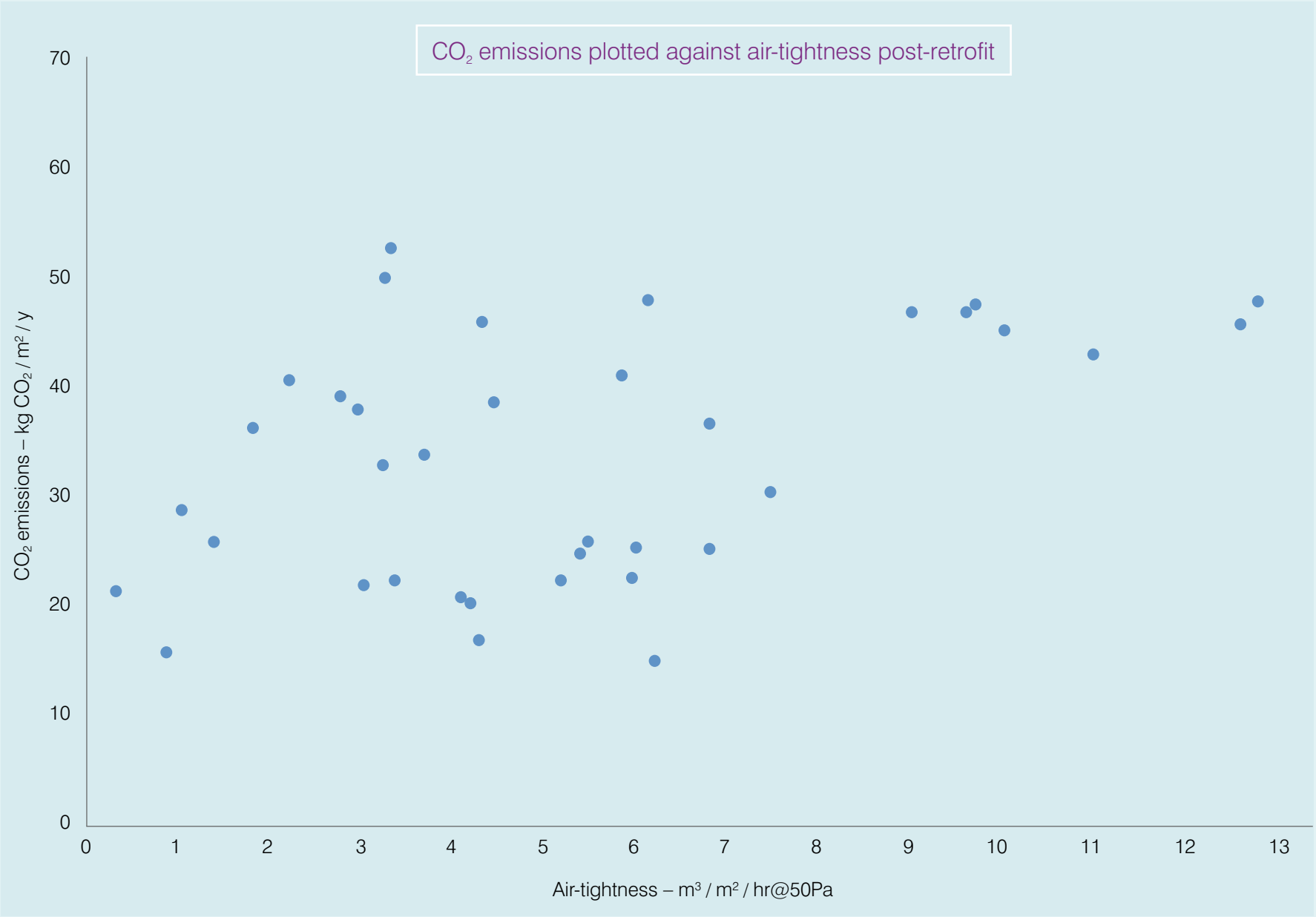
air-tightness less than 1 m^3/m^2/hr@50Pa

Air-tightness results (against 87 properties)



The following chart compares the results of post-retrofit air-tightness tests against the same properties' CO_2 emissions.

It appears that there may be a correlation between improved air-tightness and lower emissions. Combined with our analysis of internal temperatures and relative humidity (see next section), this suggests that a fabric-first approach based on air-tightness and effective ventilation is consistent with achieving reductions in energy use and CO_2 emissions, without compromising occupant comfort.


CO_2 emissions plotted against air-tightness post-retrofit
CO_2 emissions – kg CO_2 / m^2 / y
0
10
20
30
40
50
60
70
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Air-tightness – m^3 / m^2 / hr@50Pa

What do we know about comfort levels in Retrofit for the Future properties?

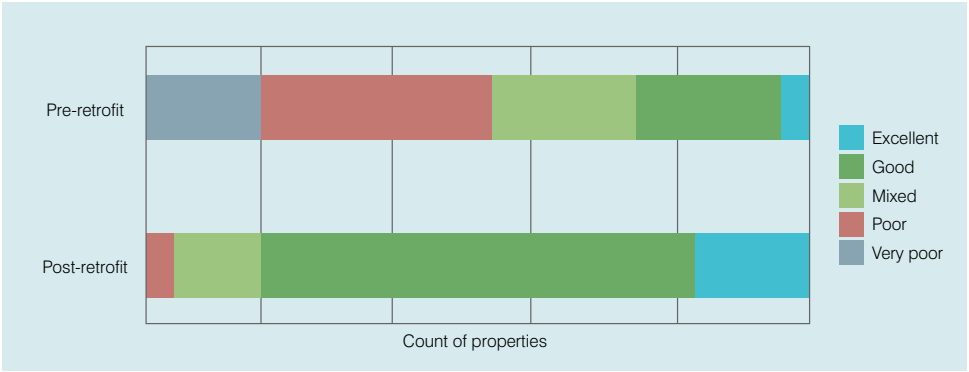
We have analysed the monitoring data provided, to understand more about the levels of comfort in Retrofit for the Future homes. In general, the properties are delivering significant CO_2 emissions reductions with no loss of comfort. That is to say, they rarely stray outside comfortable temperatures or humidity levels, or suffer from poor air quality.

Additionally, the occupants of the Retrofit for the Future properties were surveyed using surveys designed with the help of leading academics in the field.

We looked at 23 properties where we had both energy performance data and surveys recording occupants' reported levels of comfort before and after retrofit. In 22 of these properties, occupant comfort had either improved or remained the same after retrofit. Of the 13 properties with the lowest CO_2 emissions in our analysis, 12 reported either good or excellent levels of comfort, indicating that comfort does not need to be compromised by delivering low-carbon retrofits. We are investigating further into the reasons why mixed or poor comfort was reported in some cases.

The chart below shows the results from a survey of occupants' reported comfort in the retrofitted homes, compared to their reported comfort in the home they lived in beforehand, which was sometimes the same house and sometimes a different house.

Perceived comfort of property



Temperatures in Retrofit for the Future properties

We looked at 20 properties where we had internal temperature data.

The monitoring data suggests that the vast majority of these properties are having no problems maintaining comfortable temperatures between 19 degrees and 25 degrees during occupied hours.

Only one property is identified as having persistent overheating issues. Four others had internal temperatures below 19 degrees or above 25 degrees on regular occasions. However, residents in all of those with monitored temperatures have said that their homes offer a good level of comfort.

Humidity in Retrofit for the Future properties

We also have internal relative humidity data from the same 20 properties.

The data suggests that the vast majority of these have not faced any significant problems with high levels of internal relative humidity. Average relative humidity levels vary between 50% and 70%. Only one property had frequent incidences of relative humidity readings above 80%.

Many of the Retrofit for the Future projects achieved significant improvements in air-tightness. The recorded relative humidity levels indicate that improved air-tightness can be achieved without causing issues with relative humidity.

Comfort can be improved while delivering low carbon retrofits.

Oxford Whole House Carbon Reduction Project

The case study house is a typical Victorian, solid-brick-walled, slate-roofed, two-bedroom end terrace. Owned by Oxford City Council, the property was occupied before the retrofit works took place. The occupants were decanted during the works to a nearby vacant property.

Oxford Brookes University and Ridge Partners undertook several pre-retrofit surveys. Issues were identified, such as cold, dark spaces that were difficult to maintain at comfortable temperature levels, rising damp, condensation and movement cracks within the property.

The retrofit design responded to the specifics of the survey findings, and the specification included a combination of both external and internal wall insulation, loft insulation, loft sunpipe, mechanical ventilation with heat recovery, an efficient gas boiler, solar thermal and PV panels.

Pre-retrofit CO_2 emissions were modelled; actual in-use energy consumption was monitored and actual CO_2 emissions and running costs were calculated. The property is also being monitored for internal temperature, relative humidity and internal CO_2 levels, and it is expected that results will soon be reported.

Oxford Whole House Carbon Reduction Project	
Gross Internal Area	78 m^2
Occupancy after retrofit	two adults
Modelled pre-retrofit CO_2 emissions	104 kg CO_2 / m^2 / year
Monitored post-retrofit CO_2 emissions	20.1 kg CO_2/ m^2 / year
% reduction in CO_2 emissions, compared to modelled pre-retrofit result	80.7%
Estimated annual gas bill	£175
Estimated annual electricity bill	£273

Over 80% reduction in emissions, with energy bills less than £500.

What do we know about running costs in Retrofit for the Future properties?

We were interested in learning more about the running costs for residents living in retrofitted properties. We have approached this in two different ways: total estimated cost per year and estimated costs normalised for comparisons between properties.

Our calculations are based on an assumed cost per kWh of 4.43p for gas and 14.48p for electricity. The analysis excludes the cost of any biomass fuel as the volume of biomass consumed in the respective properties was not recorded.

Annual energy costs

We have estimated the total annual gas and electricity costs of the analysed properties. We have excluded from our analysis those properties known to contain a biomass boiler.

The lowest has estimated gas and electricity costs of £374 per year. Three more are below £500 per year, and three more are between £500 and £600 per year.

The occupant survey results for these homes suggest that, pre-retrofit, their running costs were significantly higher, and that the homes had lower levels of warmth and comfort. So the retrofits have enabled occupants to increase the warmth of their homes, as well as reducing their energy bills.

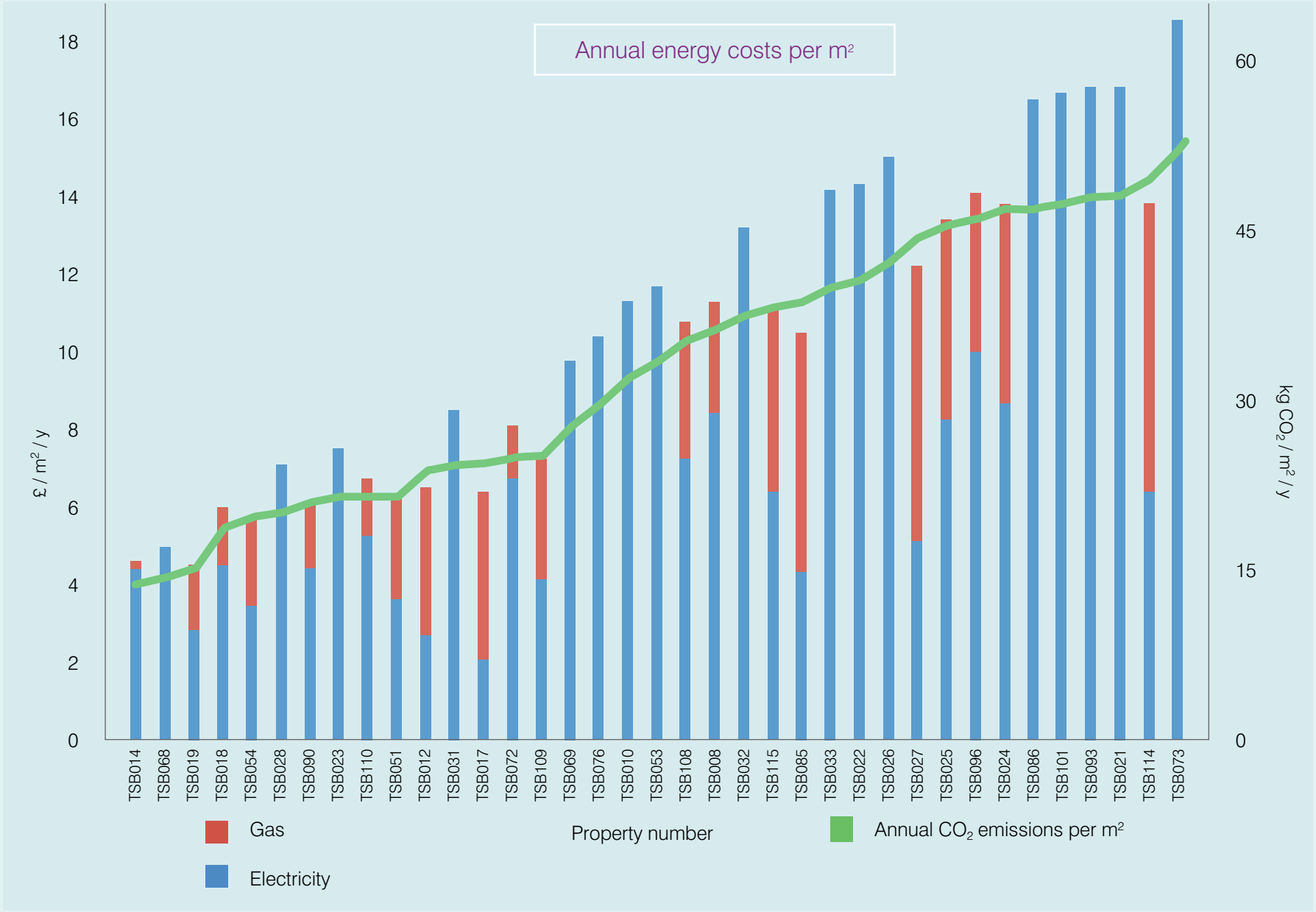
As a comparison, the average UK energy bill in 2012 exceeded £1,250. The seven best-performing retrofit properties, with annual running costs between £374 and £600, would therefore appear to be offering impressively reduced running costs, in addition to greater comfort and reduced CO_2 emissions.

We are carrying out further analysis to establish whether there are any correlations between the running costs and the solutions used within each retrofit.

Cost comparisons between properties

We are also preparing analysis of running costs for the properties, normalised to enable comparisons between properties. The following chart shows an estimate of running costs calculated as a cost / m^2 / year. We also aim to produce analysis calculated as a cost / occupant / year.

Retrofits have enabled occupants to increase the warmth of their homes


Annual energy costs per m²
£ / m² / y
kg CO₂ / m² / y
0
2
4
6
8
10
12
14
16
18
0
15
30
45
60
TSB014
TSB068
TSB019
TSB018
TSB054
TSB028
TSB090
TSB023
TSB110
TSB051
TSB012
TSB031
TSB017
TSB072
TSB109
TSB069
TSB076
TSB010
TSB053
TSB108
TSB008
TSB032
TSB115
TSB085
TSB033
TSB022
TSB026
TSB027
TSB025
TSB096
TSB024
TSB086
TSB101
TSB093
TSB021
TSB114
TSB073
Property number
Gas
Electricity
Annual CO₂ emissions per m²

Common challenges

To date, 54 Retrofit for the Future projects have submitted final reports; each provides a summary of the project team, the works as designed and as undertaken, the challenges faced, lessons learned and participants' views on how to deliver future retrofits. The final reports identify a number of common challenges.

1 Lack of competition, choice or availability of products and services

34 projects identified challenges related to products. The lack of competition or choice was seen as driving up prices for high-specification products. Price volatility was reported by ten projects, and this was usually related to novel insulation or glazing products. Where products were available, they were often subject to delays, ranging from several weeks to five months; eg glazing, which caused delays in 14 projects.

Quality issues were also faced by five projects, including products not performing to the stated specification, or arriving on site with faults. There were particular concerns about the need to import products from overseas and the lack of UK suppliers. Innovative technologies and techniques also led to concerns about the availability of guarantees in three projects.

2 Supply chain skills, quality and integration

There were particular concerns about the skills and abilities of those working on site, and it was generally recognised that the measures being installed were often new to the on-site teams. 22 projects identified a lack of skills as a challenge.

Five projects reported problems with understanding roles and responsibilities across integrated project teams. Nine found challenges associated with management, particularly the need for close oversight of works on site; for example, to ensure that internal wall insulation was installed correctly.

3 Unexpected changes to project team

Seven projects reported changes within their project team, often from contractor or subcontractor organisations going into administration, due to the recession taking hold as this programme got under way. Several projects also reported that trained site operatives were moved to other sites.

4 Site issues

These ranged from difficulties working with complex or messy products (four projects) to the unexpected discovery of issues which caused delays: asbestos, bats, wet rot in joists and structural issues to name but a few. Space constraints were identified as a problem by 16 projects. Some of these were intrinsic and internal (eg lack of space for new or larger hot water cylinders or MVHR ductwork), some were brought about by the installation itself (eg the need to re-hang doors when installing floor insulation), and some related to the exterior of the property (eg the need to retain alleyways and bin storage as a constraint to external wall insulation). One scheme also faced difficulties working in a town centre location (eg parking, scheduling deliveries).

5 Planning

Planning was cited as a barrier by six projects. In most cases, planners had been engaged early in the design process and initial discussions had been positive. There was therefore disappointment when planning permission was required, when permitted development rights were expected.

Overcoming these challenges

Many of the challenges were successfully addressed by other projects in the programme. Others have been given further consideration by the participants, with ideas generated for how they could be avoided in future. These approaches and ideas are summarised below.

1 Lack of competition, choice or availability of products and services

It is important for the project team to develop knowledge of the supply chain and the technologies in the marketplace. Some projects prepared for price volatility and lack of product availability by ensuring that they had insulation products in stock, or by pre-ordering (East Thames Group). Others worked to understand which products were likely to have longer lead times, and factored this into plans.

Change can occur within the supply chain when customers work collaboratively with suppliers. One project reported that their boiler manufacturer would not initially provide a warranty for an installation with flue gas heat recovery, but is now doing so. Another project suggested that if a manufacturer does not provide a warranty, another should be found that will. Manufacturers could also be asked for help in identifying specialist installers who can ensure that warranties are in place. The Royal Borough of Greenwich invited manufacturers to site to see how their products were being used.

2 Supply chain skills, quality and integration

Several projects sought early buy-in to the aims of the retrofit across their teams. Town and Country Housing held a presentation for maintenance staff, the design team, suppliers, consultants and residents to share plans and ideas, whilst Plus Dane Group and Gentoo explained the aims of their retrofits to site operatives. Four project teams recommended early engagement with the main contractor and other suppliers in the design process and cost discussions.

Quality of workmanship was identified as an important issue for internal wall insulation. Project teams suggested providing training of site staff, bringing experts in for on-site talks (Royal Borough of Greenwich), and having site staff attend air-tightness tests to learn about the process (Sanctuary Housing).

Some teams took even more care to ensure quality of work, and overcome these supply chain challenges. Peabody retained an M&E services consultant as an integral part of the team. Nottingham Community Housing Association started monitoring very early in the project to help diagnose and rectify any problems as soon as possible. Members of the Grove Housing Association project team even spent time living in their retrofit property so that they could snag it.

3 Unexpected changes to project team

It may be possible to place an expectation on contractors for trained site operatives to stay on site or to require that site operatives attend training. Many manufacturers supply free training, so there is no financial cost to the contractor, and probably a business gain. Harrow Council suggested that with complex technologies a manufacturer should be chosen that also installs. This makes it more likely that the desired high quality of installation will be achieved, and ensures ownership of any ongoing issues.

4 Site issues

The most common recommendation for overcoming site issues was to ensure dedicated, full-time, on-site management. Whilst this carries costs and is labour-intensive, it was generally seen as the best way of guaranteeing good quality outcomes. Gentoo has taken this approach further and is now shifting from one project manager to a team approach, to spread skills more widely and enable scalability.

Gentoo recommended building a quality assurance system into drawings to assist the contractor, whilst RCT Homes suggested ensuring that the building services design is drawn up in full detail. At a practical level, where internal wall insulation is being installed, Octavia Housing looked at room layouts and the removal of old plaster and unused chimney breasts as a way to retain space.

5 Planning

Whilst planning was an area of concern, it was not one that was readily addressed in the final reports. The advice from project teams was to engage in discussion with planners as early as possible, and to provide contingency in the time planned for obtaining consents.

Common challenges

6 Residents and their neighbours

Those projects where the residents remained in situ all reported that this caused difficulties. Mess, dust, disruption and overruns all caused stress to residents and to the project team themselves. Residents on site also had an impact on the mix of measures that were installed; for example, changing the choice of insulation to avoid losing space. Once retrofit works were complete, some project teams were frustrated that residents fell back into old energy use patterns or struggled to adapt to their new homes.

Decanting residents while works are being undertaken caused its own problems, though these were fewer in number. One project found it difficult to secure alternative temporary accommodation for a large family, whilst another faced an increase in costs of £14,000 to cover storage for residents' possessions when construction work overran.

Neighbours were also influential. Three projects faced difficulties with neighbours who objected to scaffolding, reductions in the width of alleyways or the general disruption of building works.

Three projects faced difficulties with neighbours who objected to scaffolding, reductions in the width of alleyways or the general disruption of building works.

7 Cost overruns and delays

The majority of projects faced some sort of delay and associated cost overrun. Costs changed for a number of reasons, including: increases in prices of products, failure to plan for certain activities (eg redecorating or storage costs), and remedial works after poor installation or commissioning. Costs also increased where delays occurred, be they typical delays (eg delayed delivery of windows, which was common) or unusual ones (eg discovery of asbestos or bats living in a loft). 21 projects cited something unexpected causing delays.

Other issues

Issues which were identified by a smaller number of project teams included:

- poor quality data or records relating to the property
- having to deal with multi-tenanted properties
- challenges around modelling, particularly where interventions are not included in SAP
- difficulties sourcing and working with monitoring equipment
- identifying and providing low energy appliances
- procurement issues, for example working with a framework agreement with a limited choice of (non-specialist) suppliers.

Overcoming these challenges

6 Residents and their neighbours

Residents and neighbours should be engaged in the process as early and as fully as possible. Warwick District Council and Axiom Housing suggested putting a detailed formal contract in place with the residents, to set and manage expectations.

The majority of project teams would recommend decanting residents during works. Gentoo suggested 'daytime decanting' as a more cost-effective alternative. Some project teams reported that having residents remain in situ helped with ongoing briefings and choice of products, materials and finishes.

Residents need to be well informed about their property and how to use it throughout the year. Information for residents should be well-organised and provided in a structured way. Grove Housing Association installed simple controls so that the new home would feel easier to manage than the old one.

Several of the final reports noted that the first line of support for residents is a housing association's contact centre, and recommended that staff there should be trained to advise on basic use of controls. Maintenance staff should be trained early in the process too, as they will be responsible for looking after the properties in the long run (Gentoo).

7 Cost overruns and delays

It is important to be realistic about how long tasks will take, and the associated risk of overruns. Pre-design, forward planning and research into available suppliers make a real difference (Octavia Housing, Penwith Housing Association). A clear and detailed specification steers work effectively (Yorkshire Housing), and with two schemes it was felt to be useful to keep researching and remain flexible once on site (Self Help Housing Association, Grove Housing Association). Contingency planning makes it essential to understand the complexities and dependencies in the project (The Hyde Group, North Devon Homes). Sometimes delays work in your favour. One project found a larger-than-expected underfloor void, so were able to substitute a thicker, cheaper insulation product. Bolton At Home recommended planning-in contingency time between completion of works and the resident moving in, for dealing with any final glitches.

Many of those involved with low-carbon retrofit are new to the field. Projects may overrun because it takes longer to carry out any task carefully for the first time. In future, it is likely that work will be delivered more quickly as a result of experience and learning effects. Efficiencies can be gained by integrating low-carbon retrofit into wider refurbishment works, to optimise costs (Self Help Housing Association, Hounslow Council). Four project teams also suggested the simple step of looking at the scheduling of works to take advantage of warmer, drier months.

What makes a successful retrofit project?

In answering this question, we have tried to avoid being prescriptive. We do not intend to present a template for low-carbon retrofit that would work in every situation.

We believe that creative thinking from industry and clients will improve delivery of low-carbon retrofit as the market continues to develop.

Based on the final reports, we can suggest some factors that can be expected to help a retrofit project to run smoothly and achieve its intended outcomes.

The following factors were identified in the final reports produced by Retrofit for the Future project teams.

Project planning

Time spent in detailed pre-design

Researching the market for products and suppliers early on

Detailed and realistic project planning, including extensive contingency planning and risk management

Careful sequencing of works, enabled by well co-ordinated procurement

Site management

Dedicated co-ordination of the retrofit project

Engaging and motivating the project team early on

Open and frequent communication between project team members

Understanding among site staff of the importance of achieving good air-tightness

Understanding the supply chain

Building relationships with manufacturers

Anticipating the availability, price and lead times of innovative products

Working with the suppliers of control systems to ensure that those installed are fit-for-purpose and simple to understand

Working closely with residents

Engaging residents early and frequently in the process

Decanting residents

Helping residents to understand how to manage their homes at different times of the year by explaining system controls

Training support staff (call centre, maintenance) to provide informed, ongoing help to residents

Retrofit for the Future resulted in significant innovation, and we are keen to recognise some of the more unusual steps that were taken. There remain excellent opportunities for business-led innovation in the low-carbon retrofit market.

Product innovation

Opportunities taken for product innovation are most easily identifiable:

- the Camden Council/ WHISCERS project was based around an innovative approach to off-site laser-cutting of internal wall insulation, reducing many of the problems related to space, mess and complexity that occur when cutting is carried out on site
- Isos Housing used its difficulties with importing vacuum insulation panels as a catalyst to set up a relationship with a supplier to import their products into the UK, so that they are available to other customers
- partners in the Octavia Housing and Isos Housing projects started manufacturing high-specification windows and doors to overcome a lack of available products in the marketplace
- Peabody retrofitted four properties at the same time using external wall insulation. The properties had no eaves, so the project team designed a new box gutter to enable installation without extension of the eaves
- London & Quadrant Housing are looking at how best to move from specifying individual measures to more of a 'kit' approach, whereby a predetermined palette of choices is offered. This could help to reduce costs, improve replicability and develop their skills and confidence with a fixed set of measures.

Service and process innovation

The key process innovation that was identified was the need for dedicated, knowledgeable co-ordination of the retrofit project, preferably by someone who could be on site frequently or full-time. A retrofit co-ordinator can help bring expertise and efficiencies to the planning, delivery and handover of a project, potentially reducing the costs associated with delays and reworking. There is also scope for greater involvement of M&E consultants in the design and delivery of projects. Low-energy homes are sensitive to building physics and the interaction between the different components of the whole-house system.

A more open and integrated approach to communication – across the design team, contractor, site team, residents and neighbours and the client organisation – also seemed to build greater commitment to the process and create a set of shared goals, helping to set the parameters for delivery.

One housing association used technical guidance from Holland to help them address a specific challenge, recognising that practice overseas in some aspects of retrofit may currently be more developed than in the UK.

A retrofit co-ordinator can help bring expertise and efficiencies to the planning, delivery and handover of a project, potentially reducing the costs associated with delays and reworking.

Innovation in resident engagement

The majority of projects considered that works could have been carried out more quickly and with less disruption if residents were decanted.

Daytime decanting – providing space for residents during the day and enabling them to return home in the evening – offers a hybrid option whereby the residents can be on hand to see the transformation of their home and avoid facing much of the disruption of having multiple operatives on site. This could also be an effective option when retrofit is scaled-up across multiple properties and the costs and practicalities of decanting residents may be prohibitive.

Decanting creates challenges (for example, finding a suitable local property) and this becomes more intense as efforts to retrofit properties are scaled-up by housing associations. The social housing sector will need to look at innovative ways of co-ordinating and scheduling works and providing services and facilities to residents if the need to decant residents is not addressed in other ways (eg through product innovation). In the private owner-occupier housing market, widespread decanting may not be feasible.

Skills innovation

One of the key challenges to the development of the low-carbon retrofit market is the availability of skilled staff.

The projects offered some examples of successes in training project teams, and also fed back that hiring experienced staff for specialist functions led to higher-quality and more cost-effective delivery. Access to hands-on training facilities can give operatives the opportunity to learn, helping the supply chain to expand.

Daytime decanting

Providing space for residents during the day and enabling them to return home in the evening

What challenges persist for low-carbon retrofit in the UK?

Retrofit for the Future has helped to demonstrate that the UK retrofit industry can deliver deep carbon reductions, and has identified some practical considerations for more effective delivery in future.

Some challenges remain, however, and these may need intervention at a more strategic level:

- local planning was an obstacle for many projects. Local approaches to planning help to create and preserve vibrant individual communities; however, lack of consistency in decision-making, uncertainty over what is permitted development, and the time and resources needed to secure planning permission presented challenges to Retrofit for the Future project teams
- many of the product markets are immature, either in the UK or globally. Price volatility affected project budgets and long or delayed lead-in times were frequently blamed for project overruns. If low-carbon retrofit is to scale-up in line with Government ambitions, then product markets need to mature rapidly
- the supply chain for delivering whole-house low-carbon retrofit could face capacity issues as demand grows, and there will likely be opportunities for new players. In Belfast, the Grove Housing Association project significantly influenced the supply chain in Northern Ireland, such that there are now twelve businesses operating in the low-carbon retrofit sector, whereas previously there were none.

Almost every Retrofit for the Future project experienced something unplanned: from bad weather to delayed product delivery to complaints from neighbours to subcontractors failing to arrive on site. It will be important to learn from these examples at a strategic level, and to explore how planning for risk, uncertainty and contingency can be better embedded as skills within the emerging retrofit industry.

Retrofit for the Future data set

The Retrofit for the Future data set presents researchers, policymakers and practitioners with a fantastic new resource. It contains a variety of project-specific data which can be used to help shape the retrofit market in the UK. We are committed to spreading knowledge in order to catalyse innovation, and hence are making the Retrofit for the Future data set available to all for further analysis.

The data set is held in the 'embed' database which can be accessed from **www.retrofitanalysis.org**. There you will also find a downloadable version of this report, and access to additional analysis and charts. We would appreciate your help in raising awareness of the database among your colleagues and contacts.

We are interested to know how the data from Retrofit for the Future is being used and analysed; if you produce reports or analysis of your own, please credit the source of your work and tell us about your analysis through the _connect platform (https://connect.innovateuk.org/web/retrofit).

Scaling-Up Retrofit of the Nation's Homes

We want to understand more about the relationship between costs and carbon reductions. To do this, we have launched the Scaling-Up Retrofit of the Nation's Homes competition, which aims to stimulate significant cuts in CO_2 emissions from existing homes, by enabling consortia to radically improve their retrofit offering, and so to catalyse greater market take-up. We believe that compelling value propositions can unlock the potential market for retrofit by delivering a package of retrofit measures at a competitive price point and with guaranteed levels of performance.

The competition opened on 4 March 2013. To enter, you must register by noon on 10 April 2013 and submit an Expression of Interest by 17 April 2013.

You can find out more about the Scaling-Up Retrofit competition at www.innovateuk.org/competitions

Scaling-Up Retrofit for the Nation's Homes competition

Further information

Links

Retrofit for the Future data analysis

You can access further analysis charts from this project and download this report from **www.retrofitanalysis.org**

embed database

The embed database holds data related to Retrofit for the Future projects, including the monitoring data which underlies this report and analysis. You can also access the embed database via the link above.

Low Energy Buildings website

AECB – the sustainable building association – has developed a database of Retrofit for the Future projects, cataloguing planned works to be undertaken during the programme. You can visit the Low Energy Buildings website via the link above.

Technology Strategy Board

The Technology Strategy Board is the UK's innovation agency. You can find out more about our work – including how to get involved with future competitions – at **www.innovateuk.org**

If you are interested in sharing knowledge, building networks, or in the role of innovation in transforming our building stock, you can join _connect, the online platform provided by the Technology Strategy Board. Visit **https://connect.innovateuk.org/web/guest** to find out more.

Research reports

Building Opportunities for Business: Low Carbon Domestic Retrofit Guides

The Technology Strategy Board has partnered with the Institute for Sustainability to produce this set of guides based on the experiences of the Retrofit for the Future programme. They detail the business opportunities that retrofit offers, and are particularly aimed at SMEs within the construction industry.
http://www.instituteforsustainability.co.uk/retrofitguides.html

Retrofit insights: perspectives from an emerging industry

The Institute for Sustainability commissioned the UCL Energy Institute to undertake an analysis of a selection of Retrofit for the Future projects, incorporating both project team and occupant experiences. *Retrofit insights: perspectives from an emerging industry* and two supporting research documents can be downloaded from
http://www.instituteforsustainability.co.uk/latestpublications.html

The Technology Strategy Board is a business-led executive non-departmental public body, established by the Government. Its role is to promote and support research into, and development and exploitation of, technology and innovation for the benefit of UK business, in order to increase economic growth and improve quality of life.

The Technology Strategy Board
North Star House
North Star Avenue
Swindon SN2 1UE
Telephone: 01793 442700
www.innovateuk.org

Technology Strategy Board
March T13/28
Printed on 100% recycled paper